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Novel Antenna Configurations for Wireless Broadband Vehicular Communications

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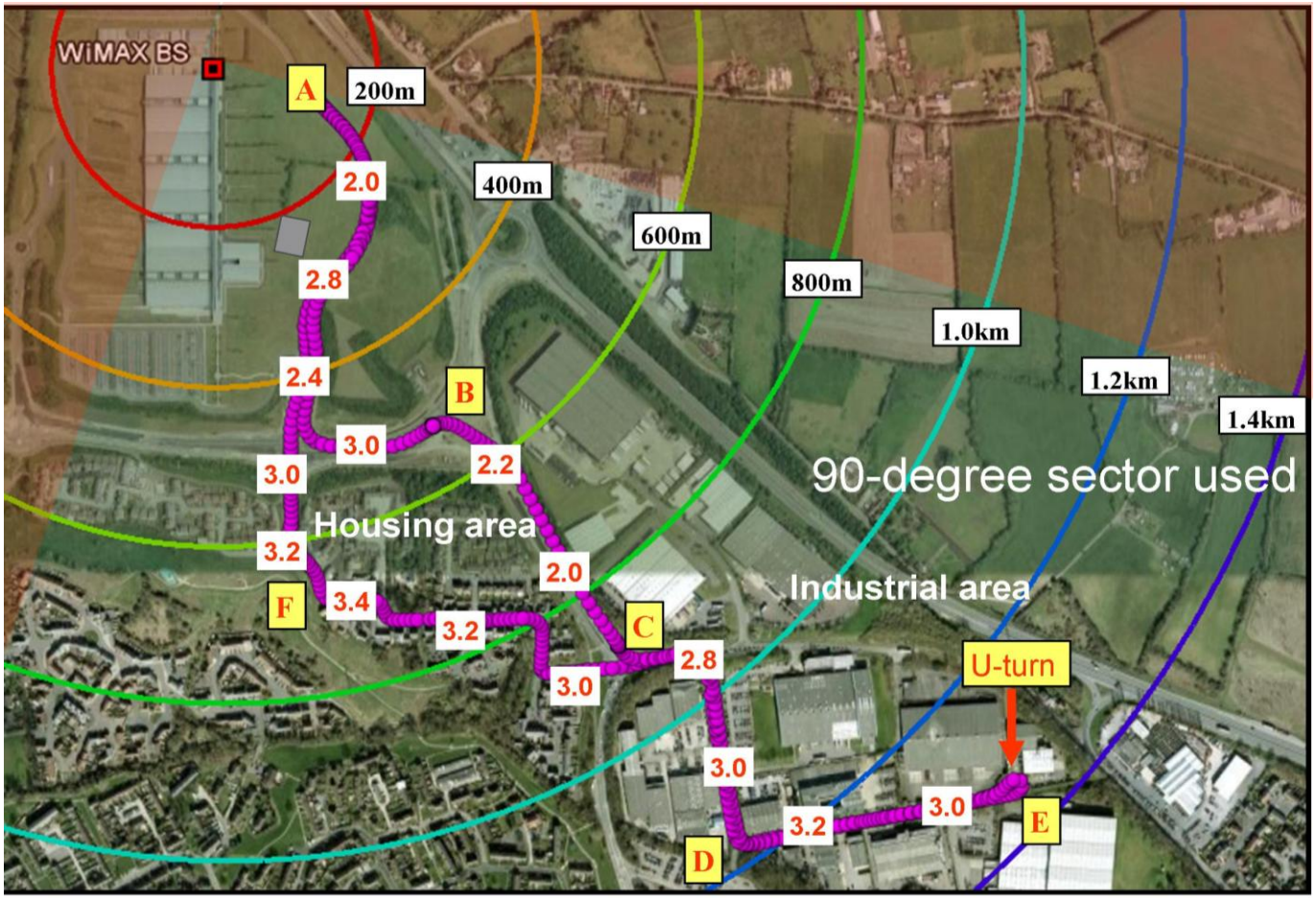
Outline

- Introduction
- Propagation Environment and WiMAX Measurement Scenario
- Omni Vs Directional Antenna (real WiMAX performance)
- Dual Slant (+/- 45) vs. Horizontal/Vertical Polarization
- Conclusion

Introduction

- Investigate performance of omni vs. directional antennas in terms of
  1. RSSI
  2. Throughput
- Investigate the effects of antenna polarization configuration on
  1. RSSI
  2. Throughput
  3. Spatial Multiplexing usage

Propagation Environment and Drive tests



Drive test route: A>>B>>C>>D>>E and back to start via D>>C>>F>>A

Red numbers: local path loss exponents

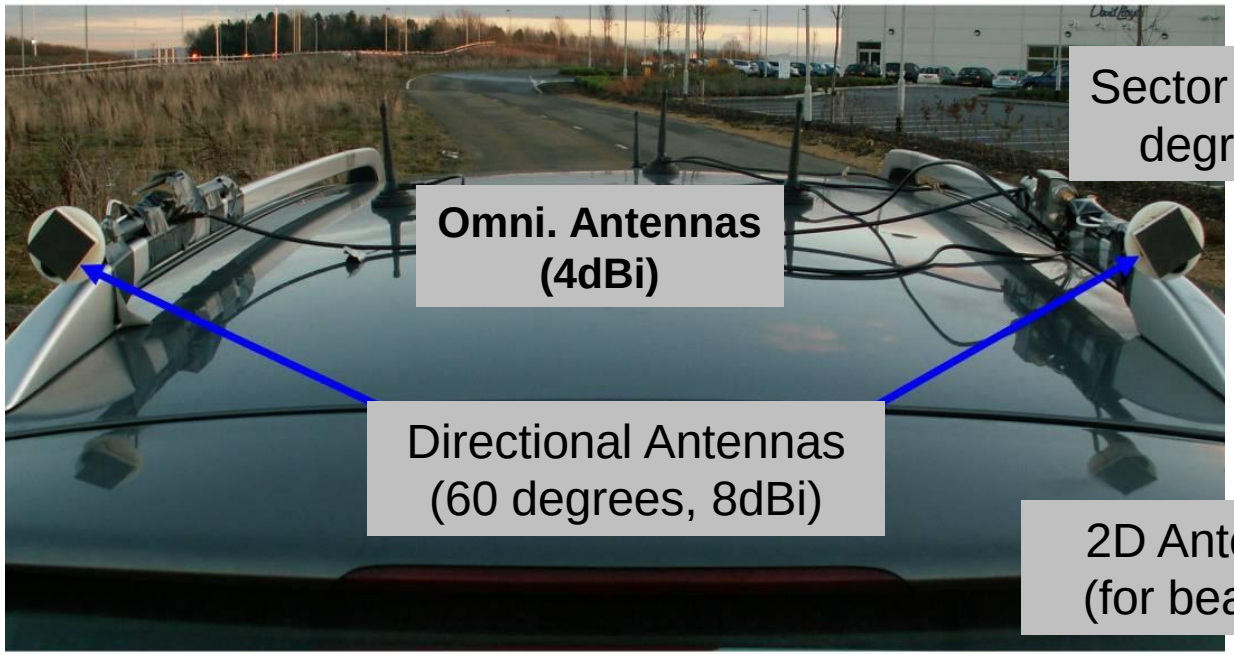
Return trip: 3.5 km at vehicular speed of 30 to 70 kmph depending on the traffic

Mobile WiMAX System Parameters

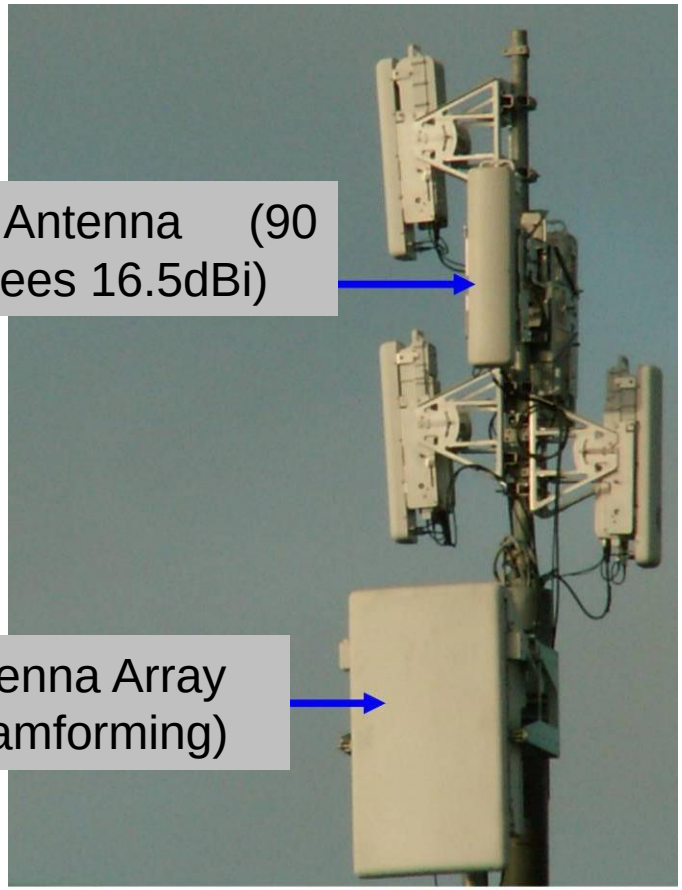
- Mobile WiMAX BS at 3.5 GHz
- Bandwidth: 5 MHz
- Sub-carriers: 1024
- BS EIRP: 46.5 dBm
- Tx config: Dual Slant
- Maximum Ratio Combining (MRC)
- MIMO 2x2 system with adaptive Modulation and Coding (AMC) and adaptive MIMO switching (AMS) turned ON

WiMAX Antennas

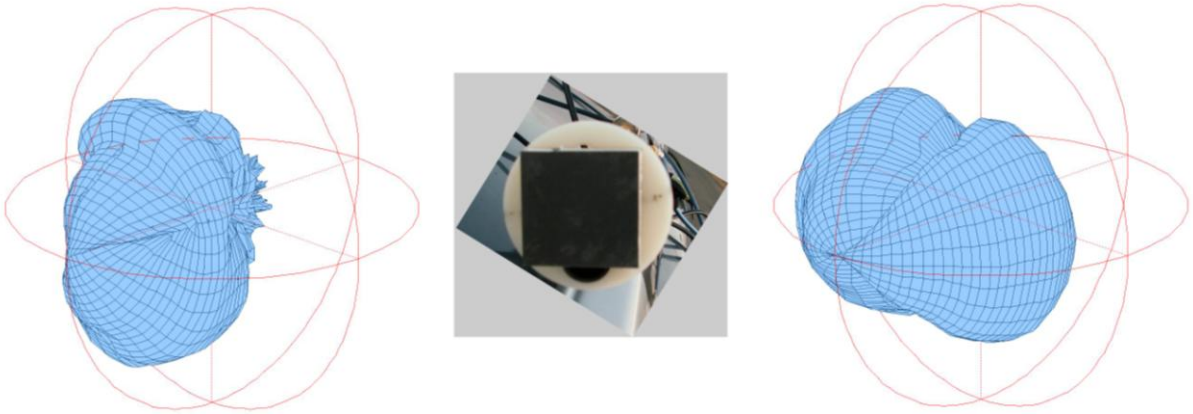
Vehicular (external) Antennas connected to PCI WiMAX cards (d=10λ)



Base Station Antennas (EIRP=46.5 dBm)

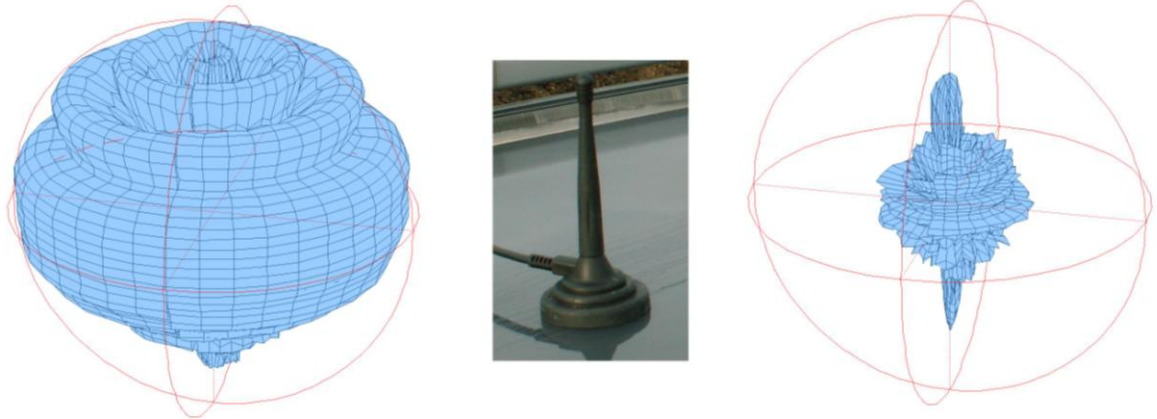


Omni vs. Directional Antennas



i) co-polar ii) cross-polar

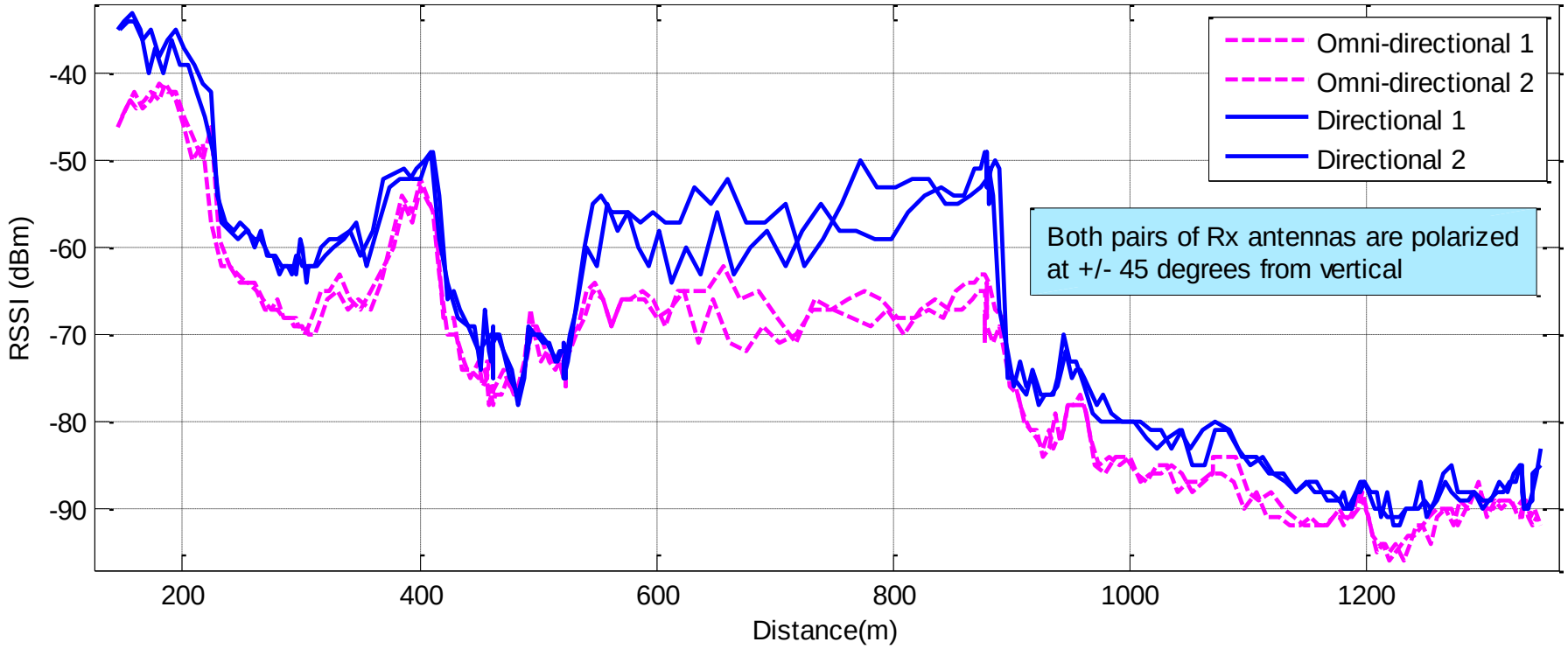
60-degree vertically polarized directional antenna at 3.5GHz with large ground plane



i) co-polar ii) cross-polar

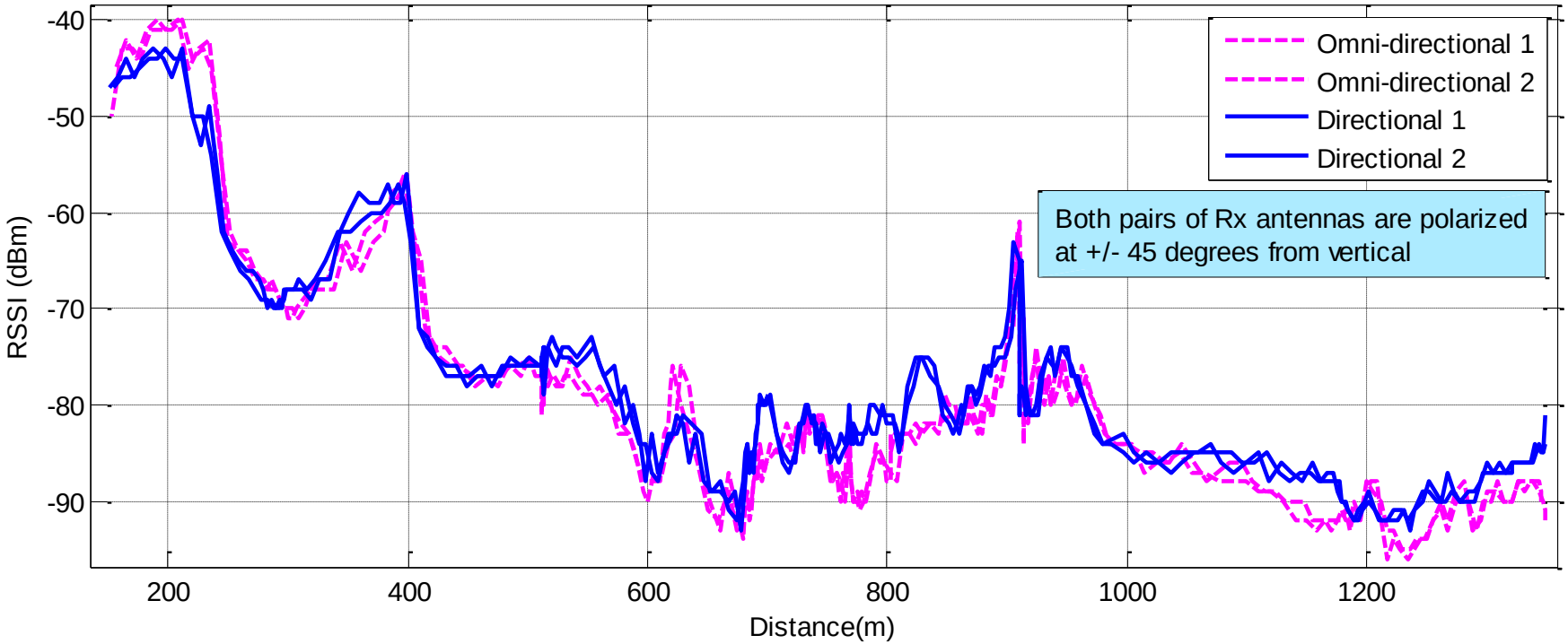
omni-directional vertically polarized antenna at 3.5GHz with large ground plane

RSSI with different Rx antennas



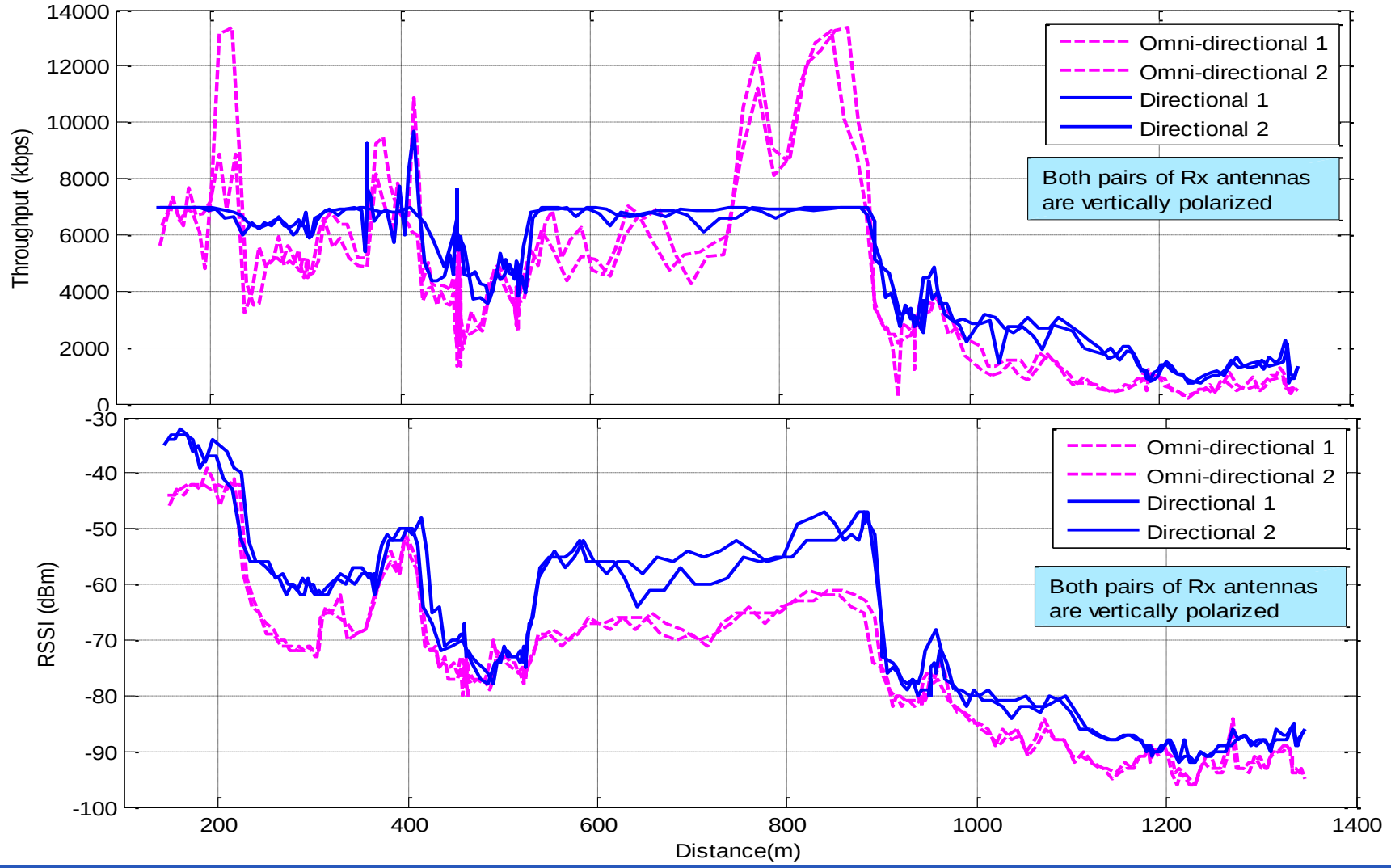
RSSI versus distance with different Rx antennas (driving away from the BS)

RSSI with different Rx antennas



RSSI versus distance with different Rx antennas (driving towards the BS)

Throughput with different antennas



MIMO Capacity Equation

$$C = \log_2\left[\det\left(I_{N_R} + \left(\frac{\rho}{N_T}\right) HH^*\right)\right]$$

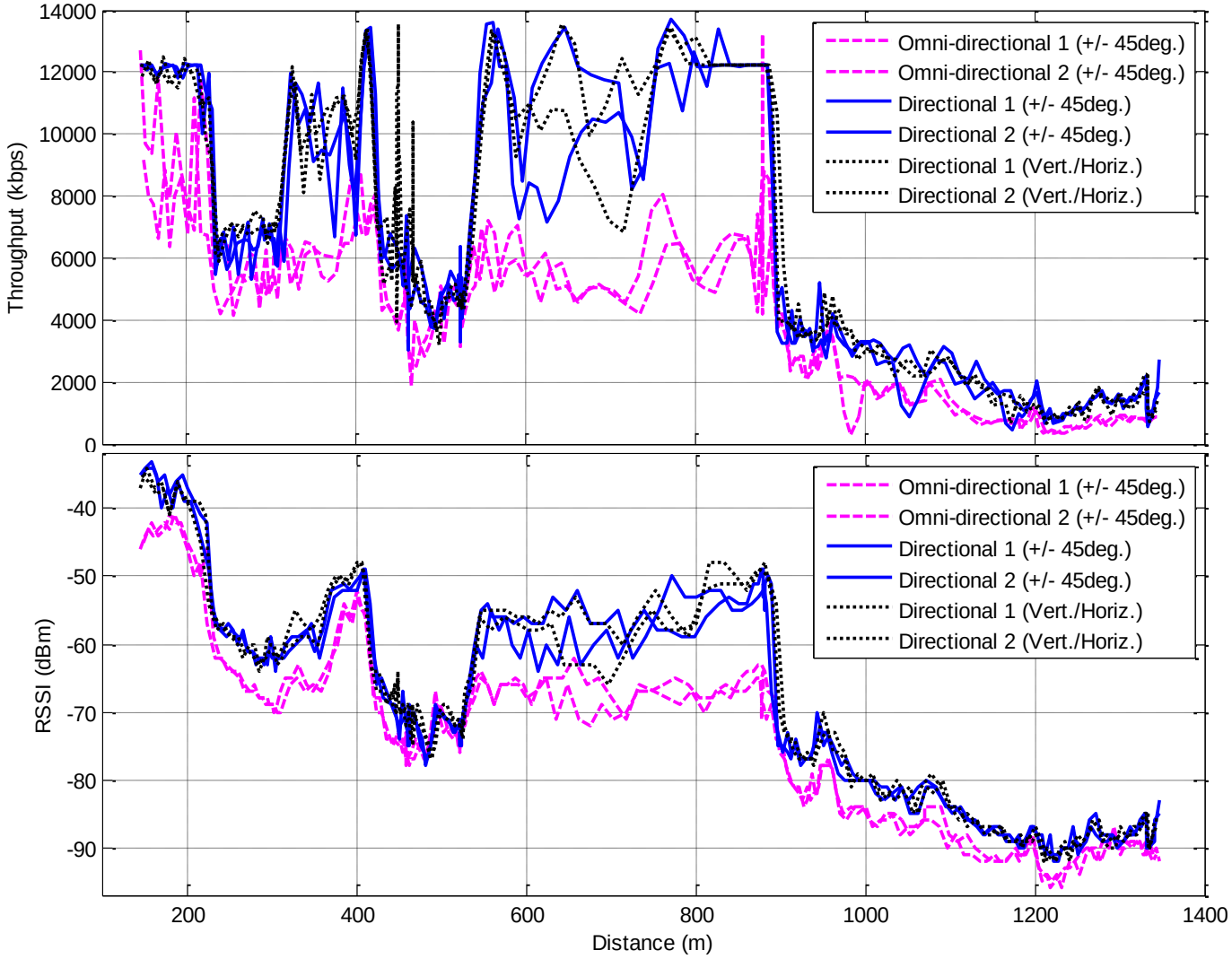
- I_{N_R} is the N_R x N_R identity matrix, N_T and N_R are the number of Tx and Rx antennas respectively
- ρ is the mean SNR per received branch, H is the power normalised channel matrix

- RSSI (or SNR) is not the only metric that determines the capacity of MIMO systems.
- MIMO systems also require low fading envelope correlations between the multiple antenna branches in order to fully exploit the capabilities of SM and STBC; This increases the determinant of the MIMO channel matrix, which enhances the theoretic capacity of the system.
- In the ideal situation, the channel experiences independent and identically distributed (iid) fading on the elements of *H*.

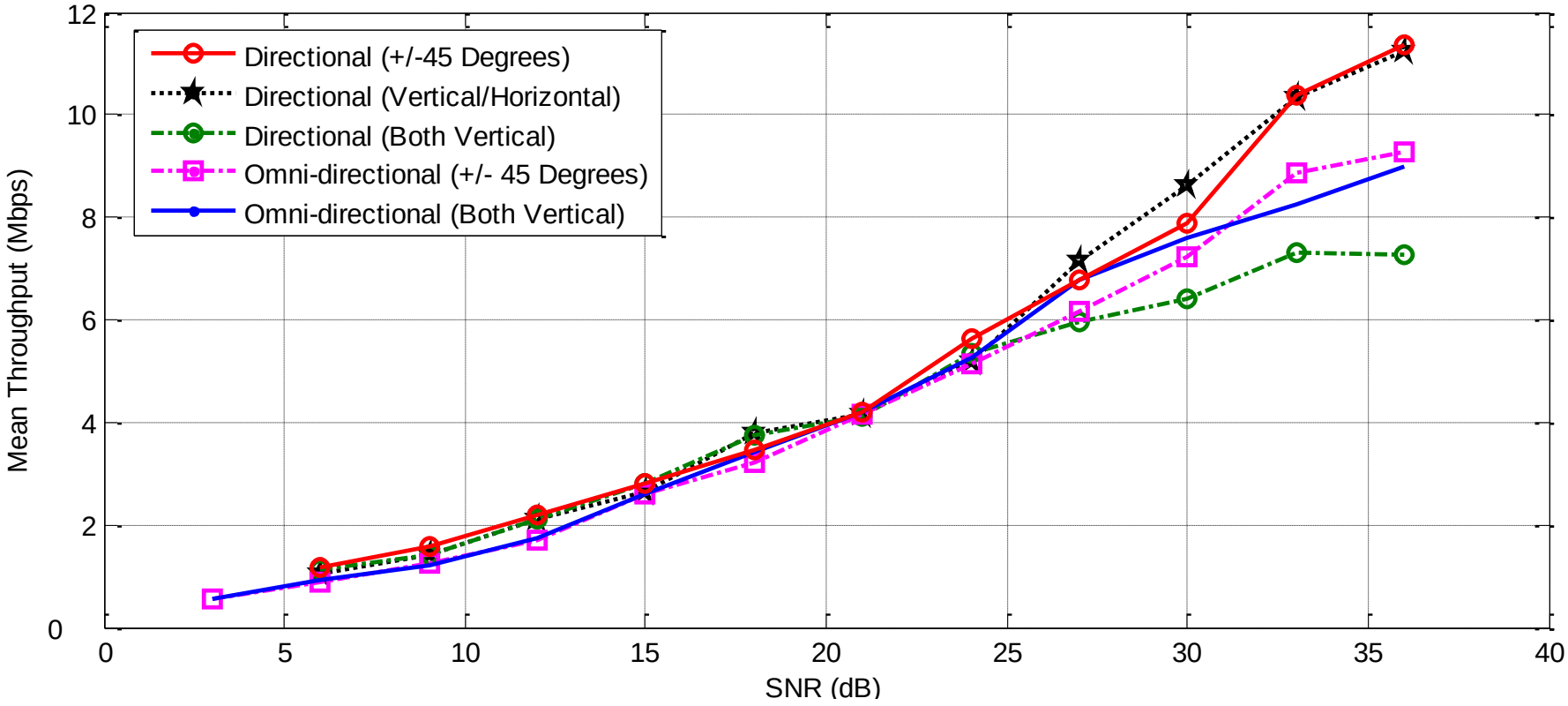
Requirements for Capacity improvement in vehicular MIMO applications

- Balanced links (similar SNR on all branches)
- Low fading envelope correlations between multiple antenna branches
- Links with strong LoS require additional actions in order to achieve low fading envelope correlations (e.g. use of dual polarization) at the receiver
- Also incorporating the effect of the large ground plane (vehicle's roof) which alters the radiation pattern of the antenna

Results with dual polarized antennas



Mean Throughput with different Antenna Configurations



Spatial-Multiplexing usage with different Rx antenna configurations on the vehicle

Spatial-Multiplexing usage (%) in LoS and NLoS conditions with different Rx antenna configurations on the vehicle					
Rx antenna	**Directional**	**Direct.**	**Direct.**	**Omni-direct.**	**Omni-direct.**
Polarization	**+/- 45 Deg.**	**Vert./ Horiz.**	**Both Vertical**	**+/- 45 Deg.**	**Both Vertical**
LoS	**77.52**	**85.52**	**37.93**	**56.08**	**59.65**
NLoS	**57.95**	**67.55**	**41.4**	**33.25**	**30.05**

Best and Worst (vehicular) Antenna Configurations

Dually polarized directional antennas support the highest usage of Multiplexing while the pair of vertically polarized directional antennas gives the least among the five antenna configurations tested

Conclusions

- Vehicular communications perform better with directional antennas aligned to the direction of motion.
- MIMO 2x2 requires balanced links and low fading envelope correlations to exploit the advantages of MIMO

Questions?

Thank you!

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